

Technical Note: Evaluating Mandibular Ramus Flexure as a Morphological Indicator of Sex

CHERYL A. HILL*

*Department of Anthropology, University of Kansas,
Lawrence, Kansas 66045*

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ABSTRACT Described as a highly reliable method of sex identification, mandibular ramus flexure is a morphological trait expressed on the posterior border of the ramus at the occlusal plane (Loth and Henneberg [1996] *Am. J. Phys. Anthropol.* 99:473–485). In a blind test, 158 mandibles were examined for the presence of flexure as defined by Loth and Henneberg, resulting in 79.1% accuracy, which is well below the reported 91–99% accuracy. Twenty-five of these mandibles were assigned the ambiguous score of 0, an outcome of a +1 score for one side, and a –1 score for the other. Seventeen mandibles were examined twice to measure intraobserver error. Only 64.7% of the scores were duplicated in the second session, suggesting difficulty in consistent identification of flexure. Low overall accuracy, an invalid scoring system, and high intraobserver error indicate that mandibular ramus flexure is an unreliable technique for estimation of sex. *Am J Phys Anthropol* 111: 573–577, 2000. © 2000 Wiley-Liss, Inc.

Loth and Henneberg (1996) described mandibular ramus flexure as an easily applied, highly reliable method for sex identification. According to their research, distinct angulation (flexure) of the posterior ramus border at the level of the occlusal plane is present in adult male mandibles. Adult female mandibles are not flexed at this point, having straighter posterior borders (Figs. 1, 2). When flexure occurs in female mandibles, it is above or below the occlusal plane. Loth and Henneberg (1996) reported remarkable results, with up to 99% accuracy, and concluded, “At 94.2%, overall accuracy from the ramus in all African and American samples combined ($N = 547$) is certainly on par with the pelvis and superior to the 90% accuracy rate from a complete skull.”

If reliable, the technique is a significant advance in sex identification for two reasons. 1) As described by Loth and Henneberg (1996), the presence of flexure can be easily discerned. This is an improvement

over most visual methods, which are burdened by individual variation, making them difficult to use and highly subjective. 2) Compared to the pelvis, the mandible is a more durable bone, commonly preserved in forensic, osteological, and fossil contexts.

Since the publication of Loth and Henneberg (1996), several reviews of it have appeared. Koski (1996) was the first to test the technique, using radiographs from 80 young adult females. He argued that flexure is present in most, rendering the technique unreliable. Loth and Henneberg (1998) countered, suggesting that Koski (1996) confused other kinds of flexure with the sexual dimorphic flexure they described, and they noted that he limited his sample to radiographs. Subsequently, Indrayana et al.

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*Correspondence to: Cheryl A. Hill, in care of David W. Frayer, Department of Anthropology, University of Kansas, Lawrence, KS 66045. E-mail: frayer@ukans.edu

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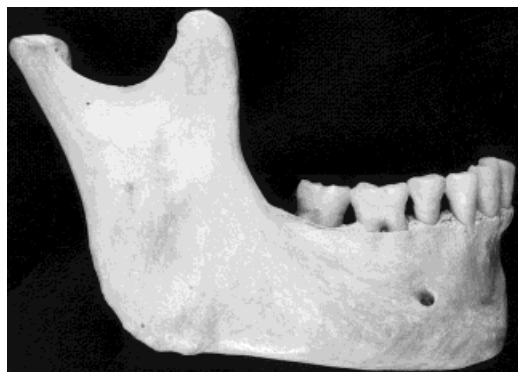


Fig. 1. An adult male mandible. The posterior border of the mandibular ramus is flexed parallel to the occlusal surface.

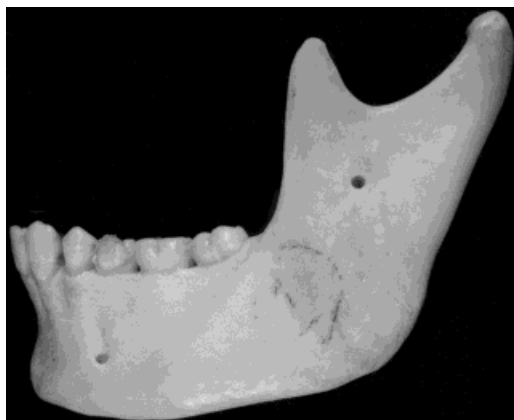


Fig. 2. An adult female mandible with a straight posterior border at the level of the occlusal surface.

(1998) applied Fourier analysis to radiographs of 150 individuals and reported 91.5% accuracy.

Most recently, Donnelly et al. (1998) studied 96 mandibles from a forensic collection of known sex and a Native American sample where sex was estimated from the pelvis. Two observers, working independently, scored the mandibles in four different sessions. Their overall prediction accuracy was 63–69%, well below that reported in Loth and Henneberg (1996) using bones and In-drayana et al. (1998) using radiographs. However, the sample included a large number of mandibles ($n = 80$) where sex was estimated from the pelvis, potentially clouding the reliability of the results. Moreover, the interobserver correlation was extremely low; κ equaled 0.280 for the right and 0.396 for the left, indicating that flexure was difficult to consistently identify between the two observers.

To provide a more rigorous test of the ramus flexure method, a large sample of mandibles of known sex was assembled, and the technique was applied by one observer.

MATERIALS AND METHODS

The primary sample consisted of 158 mandibles from the Hamann-Todd Collection, housed at the Cleveland Museum of Natural History. Collected during the early 20th century in Cuyahoga County, Ohio, the Hamann-Todd human skeletal collection is accompanied by complete coroner records

indicating sex, age, and ethnic origin. The 103 adult males and 55 adult females are a partial sample of the whole collection and include African-Americans ($n = 65$) and European-Americans ($n = 93$). The sample contains 16 “pathological” mandibles, determined by antemortem tooth loss of two or more posterior teeth (Loth and Henneberg, 1996).

To keep my observations free of advance knowledge about the sex of any specimen used in this study, Lyman Jellema of the Cleveland Museum of Natural History independently selected the mandibles for my observations. Only catalogue numbers were used to identify the specimens, and these hold no clues as to sex, age, or ethnic origin. Each mandible was examined for the presence of flexure, disregarding any other indicator of sex. Following the exact descriptions of Loth and Henneberg (1996), rami with flexure at the posterior border were assigned a score of +1 and those that were straight were assigned a score of –1. The left rami were scored first on all the specimens and then the right rami, with the scores entered on different spreadsheets to prevent bias. The mandibles were also scored from both medial and lateral views, with each individual assessment entered independently. The left and right scores from the lateral view were added for total scores ranging from –2 to +2. Following Loth and Henneberg (1996), scores of –2 and –1 were

TABLE 1. Overall accuracy of mandibular ramus flexure, from a lateral view¹

	N	Scores				Accuracy (%)
		- 1 and - 2		0, + 1, and + 2		
		N	%	N	%	
European-American						
Males	65	7	29.2	58	84.1	89.2
Females	28	17	70.8	11	15.9	60.7
Total	93	24	100.0	69	100.0	80.6
African-American						
Males	38	2	12.5	36	73.5	94.7
Females	27	14	87.5	13	26.5	51.9
Total	65	16	100.0	49	100.0	76.9
Overall total	158	38	24.1	120	75.9	79.1

¹ Following Loth and Henneberg (1996), scores of -2 and -1 are female, and 0, +1, and +2 are male.

TABLE 2. Overall accuracy of mandibular ramus flexure from a medial view¹

TABLE 2. Social accuracy of adolescents' ratings given to mothers' stress						
	N	Scores				Accuracy (%)
		-1 and -2		0, +1, and +2		
		N	%	N	%	
European-American						
Males	65	6	27.3	59	83.1	90.7
Females	28	16	72.7	12	16.9	57.1
Total	93	22	100.0	71	100.0	80.6
African-American						
Males	38	3	18.8	35	71.4	92.1
Females	27	13	81.2	14	28.6	48.1
Total	65	16	100.0	49	100.0	73.8
Overall total	158	38	24.1	120	75.9	77.8

¹ -2 and -1 are female, and 0, +1, and +2 are male.

identified as female, while mandibles with scores of 0, +1, and +2 were considered male.

To test for intraobserver error, an additional sample ($n = 17$) of known sexed individuals from Kansas State University was examined. This was a separate study and these data were not included in the sex accuracy analysis. The forensic sample of 4 adult females and 13 adult males included European-Americans ($n = 11$), Asian-Americans ($n = 4$), and African-Americans ($n = 2$). Following the procedure outlined above, the mandibles were scored twice, in June and then in November 1998. Results of the first session were unknown at the time of the second, and the mandibles were arranged differently during the two sessions.

RESULTS AND DISCUSSION

The prediction accuracy was consistently less than reported by Loth and Henneberg (1996). Of the 158 mandibles in the Hamann-Todd sample, only 79.1% were correctly identified, using a lateral view of mandibular ra-

mus flexure as the sole indicator of sex (Table 1). For males, the accuracy was 91.3%, but the accuracy for females was only 56.4%. These results were similar for both ethnic groups, where overall African-American and European-American accuracy in predicting sex was 76.9% and 80.6%, respectively. However, the African-American males' accuracy of 94.7% was the highest of the sample, while the African-American females were most often sexed incorrectly (51.9% correct). European-American males have 89.2% prediction accuracy and females only 60.7% accuracy. These discrepancies between the sexes were unexpected and indicate that flexure is more likely to be identified than its absence, leading to consistent misidentification of females.

Virtually identical results were obtained when a medial view was used, with an overall accuracy of 77.8% and better accuracy with males than females (Table 2). A comparison of medial and lateral scores shows that 16 of the scores differed, with no effect on the overall pattern. Thus, examining the mandible either medially or laterally does not greatly affect

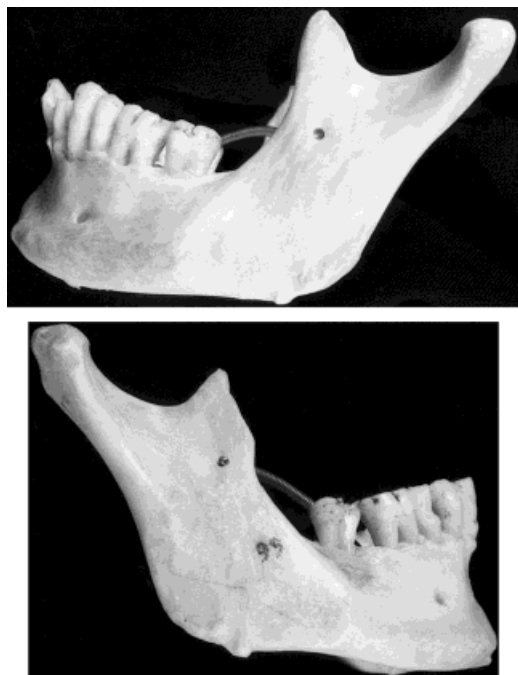


Fig. 3. An adult male mandible with a 0 score. The left was scored as -1 and the right as +1.

the technique's accuracy. In addition, removing the pathological sample (mandibles with antemortem tooth loss) did not improve results. In fact, in a sample composed of only pathological mandibles, all were correctly sexed following the technique of Loth and Henneberg (1996). This raises concerns about the technique, since if the occlusal surface is estimated, the location of the flexure is also estimated. According to Loth and Henneberg (1996), the critical sexually dimorphic flexure is present *only* parallel to the occlusal surface, but this is difficult to determine with excessive tooth loss. Despite this, these pathological mandibles show greater accuracy than the nonpathological specimens.

Further examination of the individual ramus scores suggests that the scoring system itself is flawed. Loth and Henneberg (1996) concluded that all mandibles assigned a total score of 0 were male, since only males in their African sample were scored as 0. Here, all total scores of 0 for both males and females were the result of a +1 score assigned to one side and a -1 score assigned to the other (Fig. 3). Donnelly (personal communication) reports identical results. Mandibles, with inconsistent scores for each side, are ambiguous, because different sides give opposite results. Therefore, instead of being assigned to males, these mandibles should be classified as "unable to sex." In this sample, 25 mandibles had 0 scores. When these were eliminated, the technique's overall accuracy declined to 67.7% (Table 3). The prediction accuracy for males fell to 73.9%, closer to the 56.4% calculated for females. Thus, no matter how the data were manipulated in these known sex samples, the accuracy of the technique never exceeded 80%, in contrast to the minimal 91% reported by Loth and Henneberg (1996).

In all previous studies, intraobserver error had not been reported, although Loth and Henneberg (1996) assumed that the presence or absence of flexure is easily scored, with presumably a low intraobserver error. In blind rescoring tests, only 11 (64.7%) of the 17 mandibles were assigned identical scores in the two sessions. This indicates difficulty in determining the location of flexure and a high variability in assignments by an observer. Based solely on rate of replication, the technique is unreliable. With extended practice, the intraobserver error rate might be improved, but clearly the technique is not a simple one, affording "instant" sexing expertise.

TABLE 3. Overall accuracy, when score of 0 is not sexed as male¹

Sex	N	Scores						Accuracy (%)
		-1 and -2		0		+1 and +2		
		N	%	N	%	N	%	
Males	103	9	22.5	18	72.0	76	81.7	73.9
Females	55	31	77.5	7	28.0	17	18.3	56.4
Total	158	40	100.0	25	100.0	93	100.0	67.7

¹ -1 and -2 are female, 0 is ambiguous, and +1 and +2 are male.

CONCLUSIONS

These results refute the claim by Loth and Henneberg (1996) that mandibular ramus flexure rivals the pelvis and surpasses the cranium and long bones in accurately estimating sex. Using the precise method described by them, the prediction accuracy was only 79.1%, and 67.7% when 0 scores were not used to define males. This is far below the 91–99% accuracy reported in the initial study. The results of the present study closely concur with the 63–69% accuracy reported by Donnelly et al. (1998). Thus, in the only two tests of the method done on bone rather than radiographs, the procedure has proven unreliable. In addition to its low accuracy, the technique is unreliable because: 1) it is substantially more accurate for males than females, 2) specimens with scores of 0 are ambiguous, and 3) the intraobserver error is high. Thus, mandibular ramus flexure should not be included among the battery of features used to sex skeletal remains.

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LITERATURE CITED

- Donnelly S, Hens SM, Rogers NL, Schneider KL. 1998. A blind test of mandibular ramus flexure as a morphological indicator of sexual dimorphism in the human skeleton. *Am J Phys Anthropol* 107:363–366.
- Hill C. 1999. Mandibular ramus flexure and determination of sex [abstract]. *Am J Phys Anthropol; Suppl* 28:152.
- Indrayana NS, Glinka J, Mieke S. 1998. Mandibular ramus flexure in an Indonesian population. *Am J Phys Anthropol* 105:89–90.
- Koski K. 1996. Mandibular ramus flexure—indicator of sexual dimorphism? *Am J Phys Anthropol* 101:545–546.
- Loth S, Henneberg M. 1996. Mandibular ramus flexure: a new morphological indicator of sexual dimorphism in the human skeleton. *Am J Phys Anthropol* 99:473–485.
- Loth S, Henneberg M. 1998. Mandibular ramus flexure is a good indicator of sexual dimorphism. *Am J Phys Anthropol* 105:91–92.